11:08:19 OCA PAD INITIATION - PROJECT HEADER INFORMATION 10/17/90

SUB UNDER E-21-F18

Active

Project #: E-21-F96 Cost share #: Rev #: 0
Center # : LO/24-6-R6550-0A1 Center shr #: OCA file #:
Work type : RES
Contract#: ECS-8808264 Mod #: ADMIN. Document : GRANT
Prime #: Contract entity: GTRC

Subprojects ? : N
Main project #: E-21-F18

Project unit: ELEC ENGR Unit code: 02.010.118
Project director(s):
HUNT W D ELEC ENGR (404)894-2945

Sponsor/division names: NATL SCIENCE FOUNDATION / GENERAL
Sponsor/division codes: 107 / 000

Award period: 880801 to 910331 (performance) 910630 (reports)

Sponsor amount	New this change	Total to date
Contract value	10,000.00	10,000.00
Funded	10,000.00	10,000.00
Cost sharing amount		0.00

Does subcontracting plan apply ?: N

Title: NETWORK ANALYZER FOR LASER PROBE MEASUREMENT SYSTEM

PROJECT ADMINISTRATION DATA

OCA contact: Mildred S. Heyser 894-4820

Sponsor technical contact

LAWRENCE S. GOLDBERG
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NATIONAL SCIENCE FOUNDATION
ENG/ECS
WASHINGTON, D.C. 20550

Sponsor issuing office

DONNA C. JENNINGS
(202)357-9602

NATIONAL SCIENCE FOUNDATION
DGC/ENG
WASHINGTON, D.C. 20550

Security class (U,C,S,TS) : U ONR resident rep. is ACO (Y/N): N
Defense priority rating : N/A NSF supplemental sheet
Equipment title vests with: Sponsor GIT X
EQUIPMENT GRANT - NETWORK ANALYZER FOR LASER PROBE MEASUREMENT SYSTEM.
Administrative comments -
INITIATION OF SUBPROJECT E-21-F96 (under main project E.21. F18) .

GEORGIA INSTITUTE OF TECHNOLOGY
OFFICE OF CONTRACT ADMINISTRATION

NOTICE OF PROJECT CLOSEOUT

Closeout Notice Date 04/25/91

Project No. E-21-F18 Center No. R6550-0A0

Project Director HUNT W D School/Lab ELEC ENGR

Sponsor NATL SCIENCE FOUNDATION/GENERAL

Contract/Grant No. ECS-8808264 Contract Entity GTRC

Prime Contract No.

Title NETWORK ANALYZER FOR LASER ROBE MEASUREMENT SYSTEM

Effective Completion Date 910331 (Performance) 910630 (Reports)

Closeout Actions Required:	Y/N	Date Submitted
Final Invoice or Copy of Final Invoice	N	
Final Report of Inventions and/or Subcontracts	Y	910415
Government Property Inventory & Related Certificate	Y	
Classified Material Certificate	N	
Release and Assignment	N	
Other	N	

CommentsBILLING VIA NSF LOC.

Subproject Under Main Project No.

Continues Project No.

Distribution Required:

Project Director	Y
Administrative Network Representative	Y
GTRI Accounting/Grants and Contracts	Y
Procurement/Supply Services	Y
Research Property Managment	Y
Research Security Services	N
Reports Coordinator (OCA)	Y
GTRC	Y
Project File	Y
Other	N
	N

NOTE: Final Patent Questionnaire sent to PDPI.

GEORGIA INSTITUTE OF TECHNOLOGY
OFFICE OF CONTRACT ADMINISTRATION

NOTICE OF PROJECT CLOSEOUT (SUBPROJECTS)

Closeout Notice Date 04/25/91

Project No. E-21-F18 Center No. R6550-0A0

Project Director HUNT W D School/Lab ELEC ENGR

Sponsor NATL SCIENCE FOUNDATION/GENERAL

Project # E-21-F96 PD HUNT W D Unit 02.010.118 T
GRANT # ECS-8808264 MOD# ADMIN. ELEC ENGR *
Ctr # L0/24-6-R6550-0A1 Main proj # E-21-F18 OCA CO MSH
Sponsor-NATL SCIENCE FOUNDAT /GENERAL 107/000
NETWORK ANALYZER FOR
Start 880801 End 910331 Funded 10,000.00 Contract 10,000.00

LEGEND
1. * indicates the project is a subproject.
2. I indicates the project is active and being updated.
3. A indicates the project is currently active.
4. T indicates the project has been terminated.
5. R indicates a terminated project that is being modified.

OMB Number 345-0058

NATIONAL SCIENCE FOUNDATION
1800 G STREET, NW
WASHINGTON, DC 20550

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National Science Foundation
Permit No. G-69

PI/PD Name and Address

Dr. William D. Hunt
School of Electrical Engineering
Georgia Institute of Technology
777 Atlantic Drive, N.W.
Atlanta, Georgia 30332-0250

NATIONAL SCIENCE FOUNDATION
FINAL PROJECT REPORT

PART I - PROJECT IDENTIFICATION INFORMATION	
1. Program Official/Org.	Dr. Lawrence Goldberg Quantum Electronics, Waves, and Beams
2. Program Name	Engineering Research Equipment Grant
3. Award Dates (MM/YY)	From: 8/1/88 To: 3/31/91
4. Institution and Address	School of Electrical Engineering Georgia Institute of Technology 777 Atlantic Drive, N.W. Atlanta, Georgia 30332-0250
5. Award Number	ECS-8808264
6. Project Title	Network Analyzer for Laser Probe Measurement System

This Packet Contains
NSF Form 98A
And 1 Return Envelope

Dr. William D. Hunt
ECS-8808264

PART II: SUMMARY OF COMPLETED PROJECT

An HP-8753A Network Analyzer was purchased for use with a knife-edge laser probe system. With the aggregate laser probe system the capability is now resident to measure surface acoustic wave (SAW) propagation in a variety of substrate materials and device configurations. The system has a signal-to-noise ratio (SNR) of up to 70 dB, step size increments of 0.1 μm and a spot size of 3.5 μm. With this system, measurements of SAW device attributes from 50 MHz to 1 GHz can be made. This equipment has provided the researchers within the Microelectronics Acoustics Group a capability unique at an academic institution in the United States. Researchers within this laboratory have been and will continue to be able to investigate the acoustical details of acoustic charge transport (ACT) as well as SAW devices. Matching funds were used to fund a portion of the cost of the network analyzer and a more substantial contribution from Georgia Tech allowed for the purchase of the bulk of the equipment which comprises the knife-edge laser probe system.

Dr. William D. Hunt
ECS-8808264

PART III: TECHNICAL INFORMATION

PART IV — FINAL PROJECT REPORT — SUMMARY DATA ON PROJECT PERSONNEL

(To be submitted to cognizant Program Officer upon completion of project)

The data requested below are important for the development of a statistical profile on the personnel supported by Federal grants. The information on this part is solicited in response to Public Law 99-383 and 42 USC 1885C. All information provided will be treated as confidential and will be safeguarded in accordance with the provisions of the Privacy Act of 1974. You should submit a single copy of this part with each final project report. However, submission of the requested information is not mandatory and is not a precondition of future award(s). Check the "Decline to Provide Information" box below if you do not wish to provide the information.

Please enter the numbers of individuals supported under this grant.
Do not enter information for individuals working less than 40 hours in any calendar year.

	Senior Staff		Post-Doctorals		Graduate Students		Under-Graduates		Other Participants[1]	
	Male	Fem.	Male	Fem.	Male	Fem.	Male	Fem.	Male	Fem.
A. Total, U.S. Citizens										
B. Total, Permanent Residents										
U.S. Citizens or Permanent Residents[2]:										
American Indian or Alaskan Native										
Asian										
Black, Not of Hispanic Origin										
Hispanic										
Pacific Islander										
White, Not of Hispanic Origin							1	1		
C. Total, Other Non-U.S. Citizens										
Specify Country 1.										
2.										
3.										
D. Total, All participants (A + B + C)							1	1		
Disabled[3]										

☐ Decline to Provide Information: Check box if you do not wish to provide this information (you are still required to return this page along with Parts I-III).

[1]Category includes, for example, college and precollege teachers, conference and workshop participants.

[2]Use the category that best describes the ethnic/racial status for all U.S. Citizens and Non-citizens with Permanent Residency. *(If more than one category applies, use the one category that most closely reflects the person's recognition in the community.)*

[3]A person having a physical or mental impairment that substantially limits one or more major life activities; who has a record of such impairment; or who is regarded as having such impairment. *(Disabled individuals also should be counted under the appropriate ethnic/racial group unless they are classified as "Other Non-U.S. Citizens.")*

AMERICAN INDIAN OR ALASKAN NATIVE: A person having origins in any of the original peoples of North America, and who maintain cultural identification through tribal affiliation or community recognition.

ASIAN: A person having origins in any of the original peoples of East Asia, Southeast Asia and the Indian subcontinent. This area includes, for example, China, India, Indonesia, Japan, Korea and Vietnam.

BLACK, NOT OF HISPANIC ORIGIN: A person having origins in any of the black racial groups of Africa.

HISPANIC: A person of Mexican, Puerto Rican, Cuban, Central or South American or other Spanish culture or origin, regardless of race.

PACIFIC ISLANDER: A person having origins in any of the original peoples of Hawaii; the U.S. Pacific Territories of Guam, American Samoa, or the Northern Marianas; the U.S. Trust Territory of Palau; the islands of Micronesia or Melanesia; or the Philippines.

WHITE, NOT OF HISPANIC ORIGIN: A person having origins in any of the original peoples of Europe, North Africa, or the Middle East.

THIS PART WILL BE PHYSICALLY SEPARATED FROM THE FINAL PROJECT REPORT AND USED AS A COMPUTER SOURCE DOCUMENT. DO NOT DUPLICATE IT ON THE REVERSE OF ANY OTHER PART OF THE FINAL REPORT.

TABLE OF CONTENTS

Dr. William D. Hunt
ECS-8808264

1. Introduction

The Microelectronics Acoustics Group at Georgia Tech is engaged in a focused set of research objectives which are all related to the use of microelectronics in acoustics. In specific this includes research on surface acoustic wave (SAW) devices, Bleustein-Gulyaev waves, acoustic charge transport (ACT) devices and Fresnel lens transducers for medical ultrasonics applications. This group is under the direction of Professor William D. Hunt and is comprised of four graduate students and four undergraduate students.

Georgia Tech has provided laboratory space as well as clean room facilities and some funds used to equip the laboratory. The primary shortage of the facilities for the Microelectronics Acoustics Group was the absence of a network analyzer which is a key component in a knife-edge laser probe system used to measure SAW propagation. This equipment grant addressed that need.

1.1 Specific Equipment Needs

It was important that the network analyzer purchased be computer controllable via an industry standard such as the IEEE-488 communication bus. All of the necessary components of the laser probe system already purchased satisfied this criterion. Since all of the research which would utilize this equipment involves acoustics the highest frequency of operation would be 1 GHz and as such a relatively inexpensive network analyzer could be employed effectively. The system which most closely met these requirements was the Hewlett Packard HP8753 Network Analyzer which operates from 300 KHz to 3 GHz. This choice has proved effective for the SAW and ACT work as well as for the medical ultrasonics work. In addition, the equipment has been used by other research groups within the School of Electrical Engineering at Georgia Tech for work on microactuators and for acoustic detection of discharges within power transformers.

1.2 Budget

The amount requested from NSF for this equipment was $21,708 and Georgia Tech provided matching funds of $10,962. Therefore the total amount that was available for the entire system was $32,670.

2. Equipment Purchased

This section provides a description of the equipment that was purchased.

2.1 Description

The complete knife-edge laser probe system is shown in Figure 1. The system has been assembled and computer code has been written and it has been a functioning unit since May of 1989. The various components of the system which were purchased under this NSF grant are listed below.

- Hewlett Packard HP8753B Network Analyzer: This network analyzer operates from 300 KHz to 6 GHz and has an IEEE-488 interface connection. ($22,950)

- Hewlett Packard HP85046A 50 Ohm S-Parameter test set: This piece of equipment is necessary for the network analyzer to be used to make S-parameter measurements. ($7,020)

- Miscellaneous RF connectors, attenuators and amplifiers: These are necessary components of the aggregate system. ($2,700)

The total cost of the hardware listed above was $32,670.

3. Research Performed on the System

The network analyzer purchased under this grant has been used for a variety of projects and is planned for use in a good many more. The completion of the knife-edge laser probe system has given us a very unique position as a research group. Because we have this facility we have been able to attract funding from industrial and government sources. Beyond its use as a component of the knife-edge laser probe system, the network analyzer has been used in our research in medical ultrasonics and has been used by other faculty and students for research on microactuators and for work on acoustic detection of electrical discharge in power transformers. We will describe briefly the research projects being conducted within the Microelectronics Acoustics Group.

3.1 Acoustic Charge Transport Devices

In this section we will describe the work which has been conducted and work which is planned or underway which will utilize the network analyzer.

3.1.1 Completed Research

The network analyzer was used in some joint research conducted with United Technologies Research Center (UTRC) on heterostructure ACT devices. This work took

place over the period of two years and was presented at the 1990 IEEE MTT Symposium and is described in [1]. Other completed work involves SAW propagation in GaAs and in superlattices [2],[3]. This work is laying a solid foundation for future research on ACT devices which will require extensive knowledge of the SAW propagation properties in these various substrate materials.

3.1.2 Future Research

Currently research projects are underway which are expected to enhance charge transfer efficiency and dynamic range in ACT devices. In addition we are conducting research on multichannel ACT devices which require cleverly designed acoustic waveguides. This work will include investigations of ZnO on GaAs devices. Currently there are two Ph.D students involved in this work and if some the two large proposals which have been submitted to DOD agencies are funded it is likely that three or four more Ph.D. students will become involved in this research. This equipment is expected to be the fundamental piece of machinery in our research efforts.

3.2 SAW Devices

In this section we will describe the work on SAW devices which has been conducted and work which is planned or underway which will utilize the network analyzer.

3.2.1 Completed Research

Some research was conducted with RF Monolithics in Dallas, Texas on unidirectional transducers. This work was relatively short in duration and did not lead to any publications. The work did, however, prove useful in the company's product development efforts. In addition, there is a Ph.D. student in the group conducting research on Bleustein-Gulyaev (BG) waves in GaAs and Quartz. This student is quite far along in his research and is expected to graduate within the next year or two. He has been quite productive [4]-[7] and the laser probe system is a very important tool in his research.

3.2.2 Future Research

A grant was obtained from Bell Northern Research (BNR) to conduct research on SAW devices for communication systems. This agreement was signed in March 1991 and promises to be a rich collaborative arrangement. The knife edge laser probe was one of the things that BNR has repeatedly mentioned as an important feature of our capabilities. We are particularly looking forward to this work as it will have a very direct impact on BNR's telecommunication business and will find its way into this venue rather quickly.

If the work on BG waves demonstrates favorable results we expect to continue this work as it relates to the high frequency surface transverse wave (STW) device work being conducted elsewhere. A portion of our current efforts involve the development of laser probe techniques for the measurement of the details of BG wave and STW propagation.

3.3 Medical Ultrasonics

In this section we will describe the work on medical ultrasonics which has been conducted and work which is planned or underway which will utilize the network analyzer.

3.3.1 Completed Research

Work is being conducted in the group on the development of polyvinylidene fluoride (PVDF) Fresnel transducer for use ultimately in the monitoring of carotid plaque progression. Thus far we have designed and built a number of these transducers to operate at 10 MHz and have measured their performance. We have also compared this experimental data with extensive theoretical modelling [8]. The network analyzer has been utilized to measure the transducer impedance which in turn gives us considerable information about the operation of the transducer. This work has attracted funding from the American Heart Association and from the National Institutes of Health.

3.3.2 Future Research

In the future we plan to further develop the transducer design establish a better measurement system for the evaluation of the acoustic field response. In addition, we are currently conducting research on the transducer model which will utilize the network analyzer heavily to determine the impact of loss mechanisms in the PVDF material.

3.4 Other Research Efforts

We have made the network analyzer available to other research groups at Georgia Tech. This section describes those efforts. We have not collaborated with these researchers. The network analyzer is by no means the key equipment in either of these projects but it has proved useful.

3.4.1 Microactuators

Professor Mark Allen in the School of Electrical Engineering has a research program on microactuators and has utilized the network analyzer from time to time to measure the input impedance of the devices his group has fabricated.

3.4.2 Acoustic Detection of Electric Discharge in Power Transformers

Professor Teddy Puttgen in the School of Electrical Engineering is a research program in this area and has used the network analyzer on a fairly regular basis to measure the input impedance of the transducers being fabricated in his group in the conduct of his experiments.

REFERENCES

[1]. W. J. Tanski, S. W. Merritt, D. E. Cullen, R. D. Carroll, E. J. Branciforte, R. N. Sacks, and W. D. Hunt, "Heterostructure acoustic charge transport technology for programmable transversal filters," *1990 IEEE MTT Symposium Digest*, pp. 1107-1110, May 1990.

[2]. Y. Kim and W. D. Hunt, "Acoustic fields and velocities for surface acoustic wave propagation in multilayered structures: An extension of the Laguerre polynomial approach," *Journal of Applied Physics*, vol. 68, no. 10, pp. 4993-4997, November 15, 1990.

[3]. W. D. Hunt, Y. Kim, and F. M. Fliegel, "A synopsis of surface acoustic wave propagation in {100}-cut <110>-propagating gallium arsenide," to be published in the February 15, 1991 issue of the *Journal of Applied Physics*.

[4]. V. M. Bright and W. D. Hunt, "Bleustein-Gulyaev waves in gallium arsenide and other piezoelectric cubic crystals," *Journal of Applied Physics*, vol. 66, no. 4, pp. 1556-1564, August 1989.

[5]. V. M. Bright and W. D. Hunt, "Acousto-optic interactions between optical waves and Bleustein-Gulyaev surface acoustic waves in gallium arsenide and other piezoelectric cubic crystals," *Journal of Applied Physics*, vol. 67, no. 2, pp. 654-662, January 1990.

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[7]. V. M. Bright and W. D. Hunt, "Analysis of Bleustein-Gulyaev wave propagation under thin periodic metal electrodes," accepted for publication in the *Journal of Applied Physics*.

[8]. M. Z. Sleva and W. D. Hunt, "A PVDF Fresnel Lens Transducer," presented at the 1990 IEEE Ultrasonics Symposium in Honolulu, Hawaii, December 1990, and to be published in the conference proceedings.